


The Planetary Society 

THE PLANETARY REPORT

DECEMBER
SOLSTICE **2021**

VOLUME 41, NUMBER 4

planetary.org

THE YEAR IN PICTURES

2021 IN PERFECT FOCUS



DOING MORE TOGETHER, APART

Highlights from a year of advocating, educating,
innovating and collaborating in the virtual world

by Bill Nye

BILL NYE
Chief Executive Officer

JENNIFER VAUGHN
Chief Operating Officer

CO-FOUNDERS
CARL SAGAN
1934-1996

BRUCE MURRAY
1931-2013

LOUIS D. FRIEDMAN
Executive Director Emeritus

BOARD OF DIRECTORS
Chairman of the Board
DANIEL T. GERACI
Global Head of Voyager Space Services

President
BETHANY EHLMANN
Professor, California Institute of
Technology; Research Scientist,
Jet Propulsion Laboratory

Vice President
HEIDI HAMMEL
Executive Vice President,
Association of Universities for
Research in Astronomy

Secretary
JAMES BELL
Professor, School of Earth
and Space Exploration,
Arizona State University

Treasurer
LON LEVIN
President and CEO,
GEOshare LLC

JOHN LOGSDON
Professor Emeritus, Space
Policy Institute, The George
Washington University

ROBERT PICARDO
Actor

BRITNEY SCHMIDT
Assistant Professor,
School of Earth and
Atmospheric Sciences,
Georgia Institute of Technology

DIPAK SRINIVASAN
Principal Staff Member,
Johns Hopkins University
Applied Physics Laboratory

BIJAL "BEE" HAYES-THAKORE
Regional Coordinator for Asia Pacific,
Space Generation Advisory Council

FILLMORE WOOD
Vice President and Regional Counsel,
BP, retired

ADVISORY COUNCIL
BUZZ ALDRIN
ROBERT D. BRAUN
DAVID BRIN
NAGIN COX
G. SCOTT HUBBARD
GARRY E. HUNT
MARK HUNTER
BRUCE JAKOSKY
RYAN JOHNSON
RYAN KRISER
BEN LAMM
ROSALY LOPES
PETE SLOSBERG
TIM SPAHR
KEVIN STUBE
LORNE TROTTIER
NEIL DeGRASSE TYSON

AS HAS BECOME our tradition, the fourth-quarter Planetary Report looks back on 2021 in pictures. Although these images capture highlights of space exploration, as CEO of The Planetary Society, I'm equally proud of the great strides our organization made during this challenging year thanks to your support.

For a full report on The Planetary Society's work throughout 2021, go to
planetary.org/impact2021

This year, like so many of you, we mastered the art of working together while being apart. We held our first all-virtual Day of Action, connecting more people than ever with their representatives in the U.S. Congress to advocate for space. Removing the barrier of travel to Washington, D.C. enabled more of you to connect with more of them. While there's nothing quite like meeting face to face, these virtual meetings were effective. After all, a great many more of us were able to "be there" than in years past.

We also went virtual for our two-day Planetfest '21, celebrating the landing of NASA's Perseverance rover on Mars. We've held a great many Planetfests and have always loved the energy of a crowded conference hall or dance floor, but by bringing this event to people right at home, we were able to connect members and families from around the world in the excitement of this exploration milestone.

The challenges of space exploration bring out the best in us, and I believe

that in a way, the pandemic has done the same thing. By having to find new ways to do familiar things, we've learned how to better connect with our members and supporters around this planet of ours, and we're a stronger Society because of it.

I also can't look back on 2021 without talking about LightSail 2. After more than two years in orbit, our very own crowd-funded spacecraft is still sailing on sunlight, demonstrating what's possible technically and expanding our understanding of what's possible when people unite to turn a vision into reality. LightSail 2's mission isn't over yet, and we're already seeing the next generation of solar sailing spacecraft, like NASA's NEA Scout, ACS3, and Solar Cruiser, tracing the trail we blazed. As a Planetary Society member, I hope you're proud of this mission's legacy. It's possible thanks to supporters like you.

This past year has been remarkable, and there's much to be excited about in 2022. Our first announcement: Later in this magazine, you'll read about Planetary Academy, a new membership program we're launching for kids to inspire them about their place in space.

Looking back and looking forward, I'm so grateful for members like you who make all this exciting work possible. We couldn't and wouldn't do any of this without you. 🌟



BILL NYE is chief executive officer of The Planetary Society.

ON THE COVER: NASA's Perseverance rover descends on cables toward the surface of Mars in this image captured by its thruster-powered sky crane. The spacecraft successfully completed a nail-biting touchdown on Feb. 18, 2021, kicking off a mission to search for signs of past life and collect samples for return to Earth. Credit: NASA/JPL * The Planetary Report (ISSN 0736-3680) is published quarterly at the editorial offices of The Planetary Society, 60 South Los Robles Avenue, Pasadena, CA 91101-2016, 626-793-5100. It is available to members of The Planetary Society. Annual dues are \$50 (U.S. dollars) for members in the United States as well as in Canada and other countries. Printed in the USA. Third-class postage at Pasadena, California and at an additional mailing office. Canada Post Agreement Number 87424. * Viewpoints expressed in articles and editorials are those of the authors and do not necessarily represent positions of The Planetary Society, its officers or its advisers. ©2021 by The Planetary Society. All Rights Reserved. The Planetary Society and The Planetary Report: Registered Trademarks © The Planetary Society. Planetfest™ The Planetary Society.

CONTACT US: The Planetary Society, 60 South Los Robles Avenue, Pasadena, CA 91101-2016; General calls: 626-793-5100; Email: tps@planetary.org; Internet: planetary.org; Editors **JASON DAVIS** and **DANIELLE GUNN**; Contributing Editor **KATE HOWELLS**; Science Editor **BRUCE BETTS**; Technical Editor **JAMES D. BURKE**; Copy Editor **NICOLE YUGOVICH**; Art Director **LORENA A. ROBERTS** for **HEARKEN CREATIVE**; Creative Services **ANDREW PAULY**

MEMBERS CAPTURE THE COSMOS

WE ASKED OUR MEMBERS to send us their best photos of the night sky and celestial objects, and naturally, the responses were delightful. Here is a selection of the images sent to us by Planetary Society members from around the world. 🌌

Frank took this photo of the Milky Way in Arizona as part of an artist-in-residence program at the Petrified Forest National Park. He took the shot with a Sony a7S camera.

FRANK KRALJIC



Mike captured this photo of the Milky Way over Bisti Badlands with a Pentax K-3 camera.

MIKE PROCELL

Alexandra captured this image using a very simple process: setting an iPhone camera against the viewfinder of a telescope.

ALEXANDRA SWANSON



Gregory took this photo of Messier 51 on April 13, 2021 by taking a two-hour exposure with a Pentax K3II camera.

GREGORY MURRAY

Contents

DECEMBER SOLSTICE 2021

2 Your Place in Space

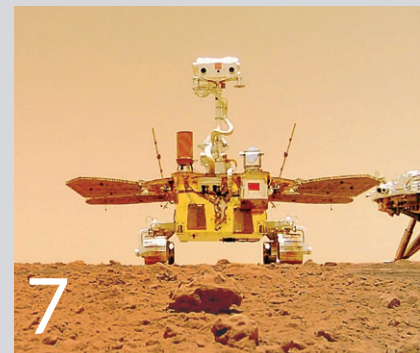
A year of virtually advocating, educating, innovating and collaborating.

3 Members on Deck

Our members share their photos of the cosmos.

4 In Context

Looking back at the days before all-digital space images.



7 The Year in Pictures

Revisiting planetary exploration highlights from 2021.



15 Night Sky Photography for Beginners

Get tips for capturing star trails and the Milky Way

20 Your Impact

The Smithsonian recognizes our LightSail 2 crowdfunded spacecraft.

22 Get Involved

Sign up for Planetary Academy, our new youth membership program.

23 What's Up?

What to see in the night sky in early 2022.

24 Space Art

A member imagines a planet orbiting two stars.

EDITOR'S NOTE: On page 6 of *The Planetary Report* September Equinox 2021 issue, we incorrectly stated that the youngest galaxy NASA's Hubble Space Telescope has ever seen was 400,000 years old and that the James Webb Space Telescope will see galaxies just 250,000 years old. Those numbers are actually 400 million years old and 250 million years old, respectively. We apologize for the error.



CATCHING THE PASSION WITH CHARLENE ANDERSON

by Jason Davis

ABOVE Charlene Anderson's passion for the Voyager missions and the photographs that were sent back — such as this Voyager 2 image of Europa — was palpable in the pages of *The Planetary Report* when she was its editor.

NASA/JPL/THE PLANETARY SOCIETY/LOREN ROBERTS

SINCE ITS FIRST ISSUE in 1980, *The Planetary Report* has featured stunning pictures to help share the passion, beauty and joy of space exploration. If you're a member who reads the print edition of this magazine, all of the images in our "Year in Pictures" feature were digital right up until the moment they were printed on the page you're touching. We are fortunate to live in an era where scenes from Mars can be posted online for the entire world to enjoy — sometimes mere hours after they were captured.

What was the process like before the internet? To remind us, we spoke with Charlene Anderson, the first staff member hired at The Planetary Society after the organization was founded by Carl Sagan, Bruce Murray and Lou Friedman. From 1980 to 2012, Anderson was the editor of *The Planetary Report*. During her tenure, she also served as the organization's associate

director. The following conversation has been edited for clarity and brevity.

JASON DAVIS When the magazine started in 1980, how did you get your hands on space images?

CHARLENE ANDERSON Most of them came through the press office at NASA's Jet Propulsion Laboratory, and we would get hard copies. Even at that point, they weren't produced with a film negative from a camera like old-time photos were. They were manufactured from spacecraft data, and they came to us on photographic paper either from the press office or directly from the scientists themselves. At press conferences, when new photos were released, they would be handed to you in a Manila envelope with captions taped onto the back. You would get your precious envelope and run back down to the office with it.

JD Did you have some kind of cataloging system for them?

CA We had the great locking file cabinet in my office. We didn't just have images from JPL. In the early '80s, we had Venera pictures from Venus. Because of Carl and Lou's connections with the Soviet Union, we would sometimes get them first. And at least in the case of the little Russian rover that landed on Mars back in the '70s, we had the only picture of that in the United States. (Anderson is referring to the Mars 3 mission, which briefly transmitted from the surface in 1972. The image of the rover was taken prior to launch).

JD Wow.

CA But then, of course, we put them in *The Planetary Report* because one of the purposes of the magazine in the early days was to get our members the best possible copies of these images. That was one reason they joined *The Planetary Society*. We worked hard on the reproduction quality so they would be getting the best possible version of these pictures.

JD How did it feel when you were seeing these images and knew that especially in the case of the Soviet ones, you were one of the only people in the world who saw them before they were published?

CA It was a great responsibility, not only because the pictures were precious but because we were performing this service for our members and the general public. We took that seriously. That's why we strove for the best possible quality when we reproduced these — because people couldn't call them up on their computer. What can I say? I felt privileged.

JD Where did *The Planetary Report* fit in the media landscape at the time? Were there any other magazines doing anything of this magnitude?

CA There was *Astronomy Magazine*

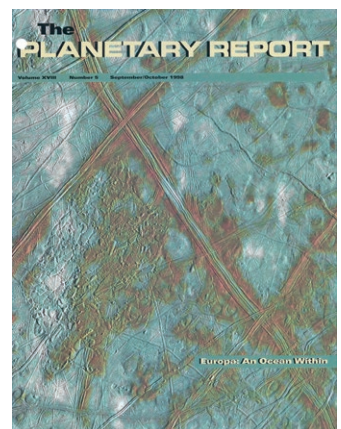
and *Sky & Telescope*. They've gone through a lot of changes, but they're still there. But because we were smaller than they were, we tried to compete on printing quality. That was our deal.

JD Do you think you were successful? When I look back at our past issues, they seem very impressive. It seems to me, not knowing what other magazines looked like at that point, that you did compete.

CA I'll tell you a little anecdote. There was a young scientist at the U.S. Geological Survey who was working on some new ways to process space images, and he was very proud of what he was producing. At that point, he was working on Io, and he slipped us some truly spectacular images made from Voyager data. He told me that he wanted to see it first in *The Planetary Report* because it was like sending your baby out into the world, and he wanted it to appear at its best. We used to pull some tricks, like occasionally paying for an extra color on the print when we could run metallic ink, and it gave the image a pseudo three-dimensional effect.

JD Speaking of Voyager, your career at *The Planetary Society* and the history of the organization itself really runs right alongside the Voyager encounters of the outer planets. What was it like seeing those images come in, especially in the case of Uranus and Neptune, when it was the first time we had seen them up close?

CA When you say "first time," that was really a big deal. We would sit in the press room during the conferences when those photos were released and just gasp and feel privileged to know that outside of the scientists, we were the first ones seeing these worlds up close. The Voyagers are my all-time favorite



TOP *Charlene (in a Society sweatshirt) enjoying a moment of levity in her second-floor office in the old headquarters on Catalina Avenue.*

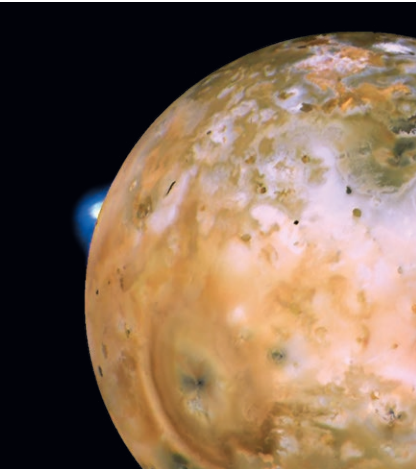
THE PLANETARY SOCIETY

BOTTOM *An image of Europa — Charlene's favorite planetary body — graced the cover of the magazine in 1998.*

NASA/JPL-CALTECH/THE PLANETARY SOCIETY



JASON DAVIS is editorial director for *The Planetary Society*.



ABOVE This Voyager 1 image of Io captured in 1979 shows a plume coming from the Loki volcanic region.

NASA/JPL/USGS

ABOVE RIGHT Saturn was Voyager 1's last planetary encounter. It captured this iconic image of the ringed giant as it left the Saturn system on Dec. 15, 1980.

NASA/JPL/GORDAN UGARKOVIC



missions. It was the first time we were seeing these worlds with such clarity. You really were an explorer riding along with the spacecraft. Pioneer had gone by Jupiter and Saturn earlier, but its cameras were not as wonderful as the ones the Voyagers carried. It was an adventure, and we knew it. There will never be anything like it again. By definition, if it's the first, it's special.

JD You were the first staff hire at The Planetary Society. Do you remember how you found out about the job and got hired?

CA I came over from The Cousteau Society. I had experience with ocean exploration, making it easy to transition to planetary exploration. In fact, at The Cousteau Society, Philippe Cousteau had an interest in space, and I was assigned space as my beat. So, I would report back to him on the discoveries that were coming out of the space program. Because I had the space beat, I got press releases from JPL, and they put out one announcing that this new organization called The Planetary Society was starting up. The address they gave was just down the hill from where I live. So I thought, "Well, I should check this out." I went and talked to Lou Friedman. A couple weeks later, he asked if I'd ever considered leaving The

Cousteau Society. And it happened to fall at a time when, yes, I was considering leaving. So, I helped start The Planetary Society.

JD Was it decided from the beginning that a magazine would be the major way that The Planetary Society did education and outreach? How important was it to Carl Sagan, Bruce Murray and Lou Friedman that we got space images out to the public?

CA At first, it was proposed that we would do a little four-page newsletter. And our consultants said, "Oh, no. You're doing a magazine. These images are the best thing you have to get people excited about space, and you have to play them up." So, that's what we did.

JD Do you have a favorite space image?

CA I think I have two. I don't know if you've noticed in past issues, but the planetary body I loved the most was Europa. After I saw those first Voyager images of the cracked surface, where you knew something was going on underneath all that ice, I fell in love with Europa. The other one would be Voyager 1's departure shot of Saturn — the spacecraft looking back from where it came and this absolutely gorgeous planetary body beneath it. 🪐



This image of Elysium Planitia on Mars was taken by Hope, the United Arab Emirates' Mars mission, on March 15, 2021 from an altitude of about 1,325 kilometers (823 miles) above the surface.

EMIRATES MARS MISSION/EXI

THE YEAR IN PICTURES

Planetary exploration in 2021

IT WAS A BIG year for planetary exploration — especially for Mars. Three new spacecraft arrived at the red planet in February: NASA's Perseverance rover, China's Tianwen-1 orbiter and rover and the United Arab Emirates' Hope orbiter. This brought the number of active spacecraft there to 11, setting a new record. Perseverance is collecting samples that will eventually be returned to Earth, Hope is collecting data to form a complete picture of the Martian atmosphere and Tianwen-1 is exploring the surface, equipped with radar to search for subsurface pockets of liquid water.

Elsewhere in the solar system, the joint European and Japanese BepiColombo mission made its first Mercury flyby. The spacecraft will pass the innermost planet five more times before entering orbit in 2025.

Japan's Akatsuki orbiter continues to study the atmosphere of Venus. The cloud-shrouded world will soon get a lot more attention thanks to this year's announcement of three new missions heading there: NASA's DAVINCI and VERITAS and the European Space Agency's EnVision.

In Earth orbit, the International Space Station received its long-delayed Russian science module Nauka, while China kicked off regular crewed visits to its new space station. The Planetary Society's member-funded LightSail 2 spacecraft continues to circle the globe, testing technologies that will help future solar sailing missions. Shortly after The Planetary Report starts arriving in mailboxes this December, the James Webb Space Telescope is scheduled to blast off on a mission to revolutionize our understanding of the cosmos.

NASA's OSIRIS-REx spacecraft left asteroid Bennu in May, carrying samples that will be

delivered to Earth in 2023 that could shed light on how ancient water and organic materials found their way to Earth. Two additional NASA asteroid missions launched in this year's final months: Lucy embarked on a journey to Jupiter's Trojan asteroids while DART, the Double Asteroid Redirection Test, was scheduled to blast off for asteroid Didymos as The Planetary Report went to press. The probe will intentionally crash into Didymos' small moon Dimorphous next year, testing a method of deflecting dangerous asteroids.

Juno continues to unpack the secrets of mighty Jupiter. In June, the NASA probe performed the first close flyby of Jupiter's moon Ganymede in more than 20 years. Still to come are up-close looks at Europa and Io.

On the outer edges of our solar system, the New Horizons spacecraft continues to cruise along as its team searches for another potential Kuiper belt object to fly by. Farther away are NASA's twin Voyager probes, now nearly 45 years old, still functioning and studying the properties of interstellar space.

Looking ahead, the second half of 2022 is packed with three scheduled planetary mission launches. JUICE, the European Space Agency's JUpiter ICy moons Explorer, will blast off on a mission to study Ganymede, Callisto and Europa. NASA's Psyche mission will begin its journey to visit what could be the exposed core of an ancient protoplanet. Finally, the European Space Agency's Rosalind Franklin rover will head to Mars equipped with a drill and miniature laboratory to search for signs of life. A Russian-built lander will deliver the rover to the Martian surface in 2023. 🚀





*An image of Ganymede
obtained by the JunoCam
imager during Juno's
June 7, 2021 flyby of
Jupiter's icy moon.*

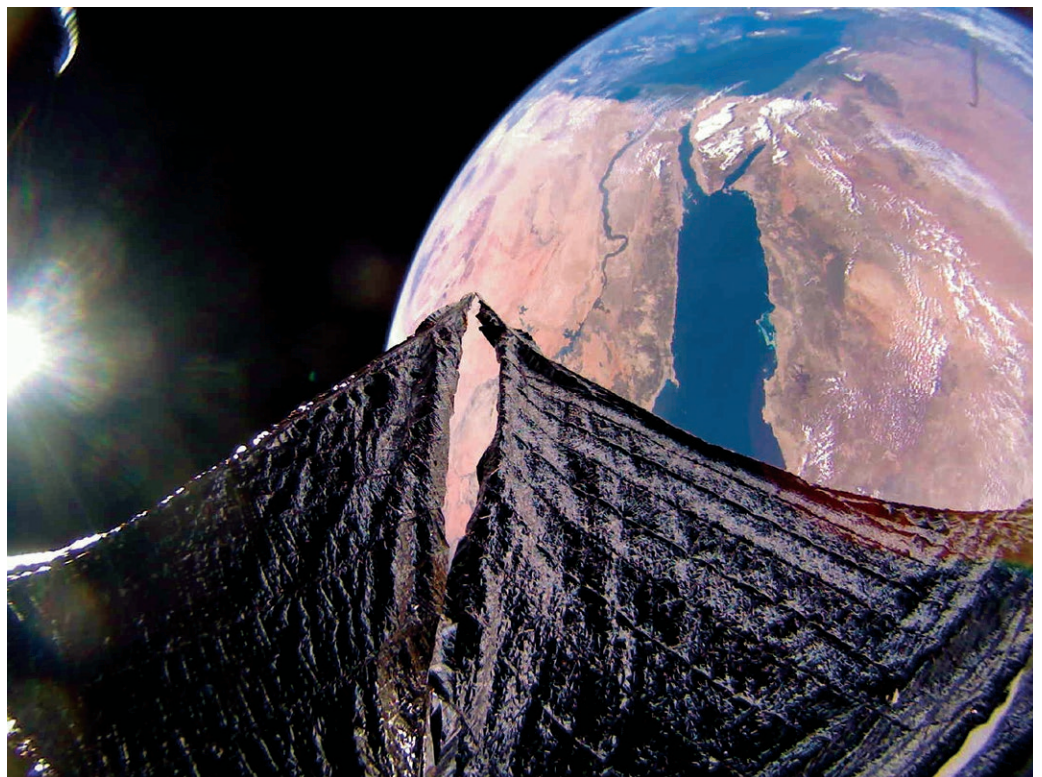
NASA/JPL-CALTECH/SwRI/MSSS

TOP This image taken by The Planetary Society's LightSail 2 spacecraft on Feb. 27, 2021 shows the Red Sea, the Nile River, the eastern Mediterranean Sea and surrounding areas. North is approximately at top right. A piece of material similar to a fishing line called Spectraline that held the spacecraft's solar panels closed prior to sail deployment can be seen in the upper right and left. This image has been color-adjusted, and some distortion from the camera's 180-degree fisheye lens has been removed.

THE PLANETARY SOCIETY

BOTTOM The ESA/JAXA BepiColombo mission captured its first views of Mercury as it swooped past in a close gravity assist flyby on Oct. 1, 2021. BepiColombo's main science mission will begin in early 2026. It is making use of nine planetary flybys in total – one at Earth, two at Venus and six at Mercury – together with the spacecraft's solar electric propulsion system to help eventually steer into Mercury orbit.

ESA/JAXA



TOP LEFT Thomas Pesquet (left) from ESA and Akihiko Hoshide (right) from JAXA work outside the International Space Station in September 2021 during a spacewalk that lasted nearly seven hours.

NASA



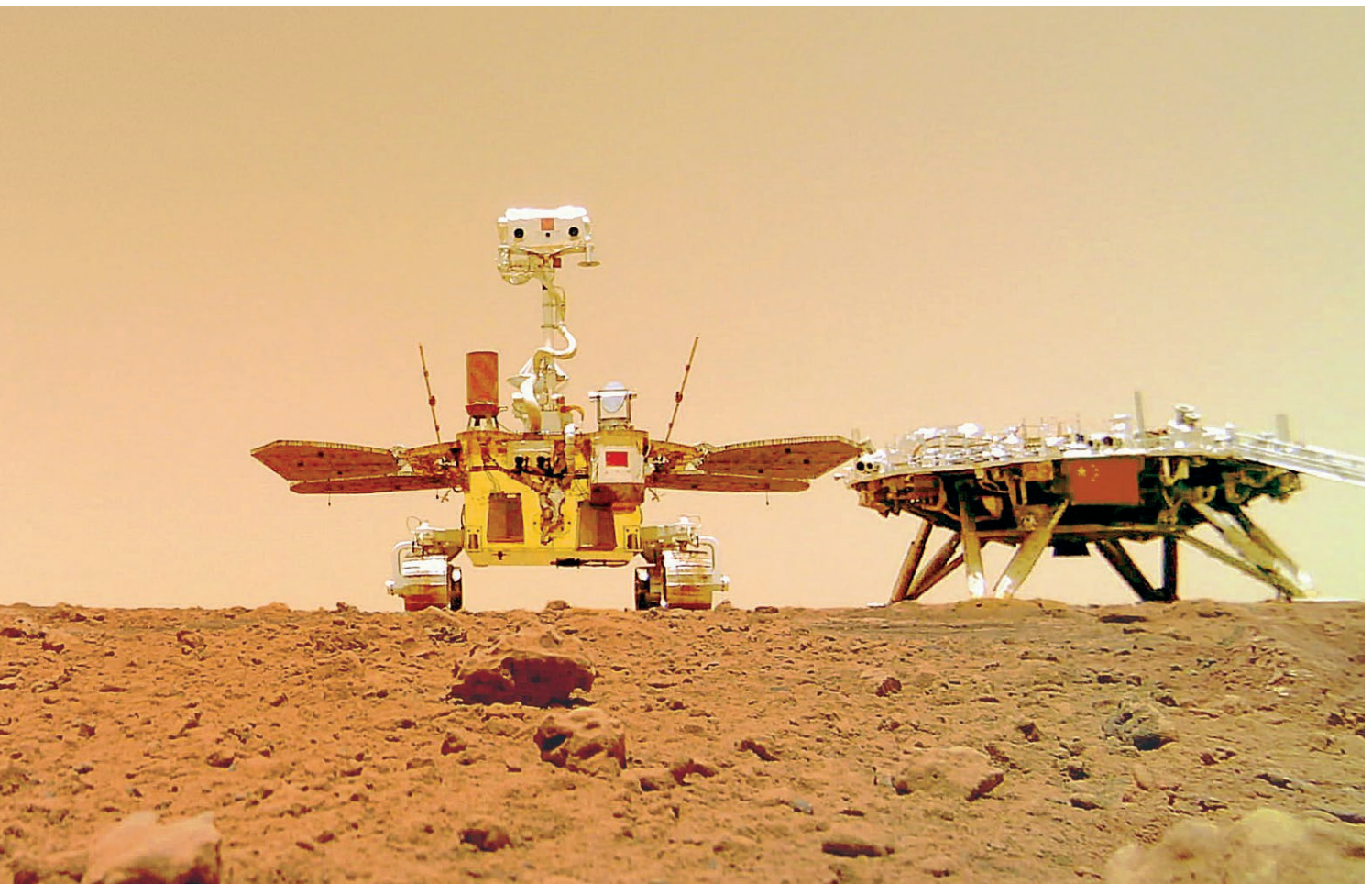
TOP RIGHT The crew of Shenzhou 12 captured this view of South Africa from China's new space station in August 2021.

CMSA



BOTTOM China's first Mars rover, Zhurong, is pictured next to its landing platform on the surface of the red planet. The rover traveled approximately 10 meters (almost 33 feet) to drop off a wireless camera before backing up in order to capture this spectacular image.

CNSA



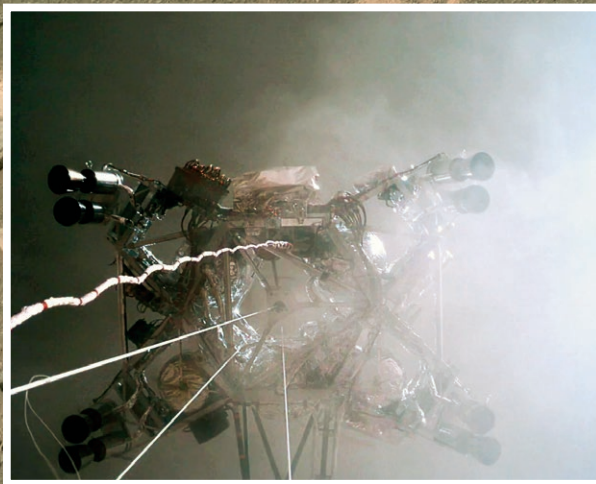
THE YEAR IN PICTURES

BELOW LEFT NASA's Perseverance rover captured this image of its parachute during descent on Feb. 18, 2021. The parachute uses binary code to spell out the credo "Dare Mighty Things" and lists the GPS coordinates of NASA's Jet Propulsion Laboratory in Pasadena, California.

NASA/JPL-CALTECH

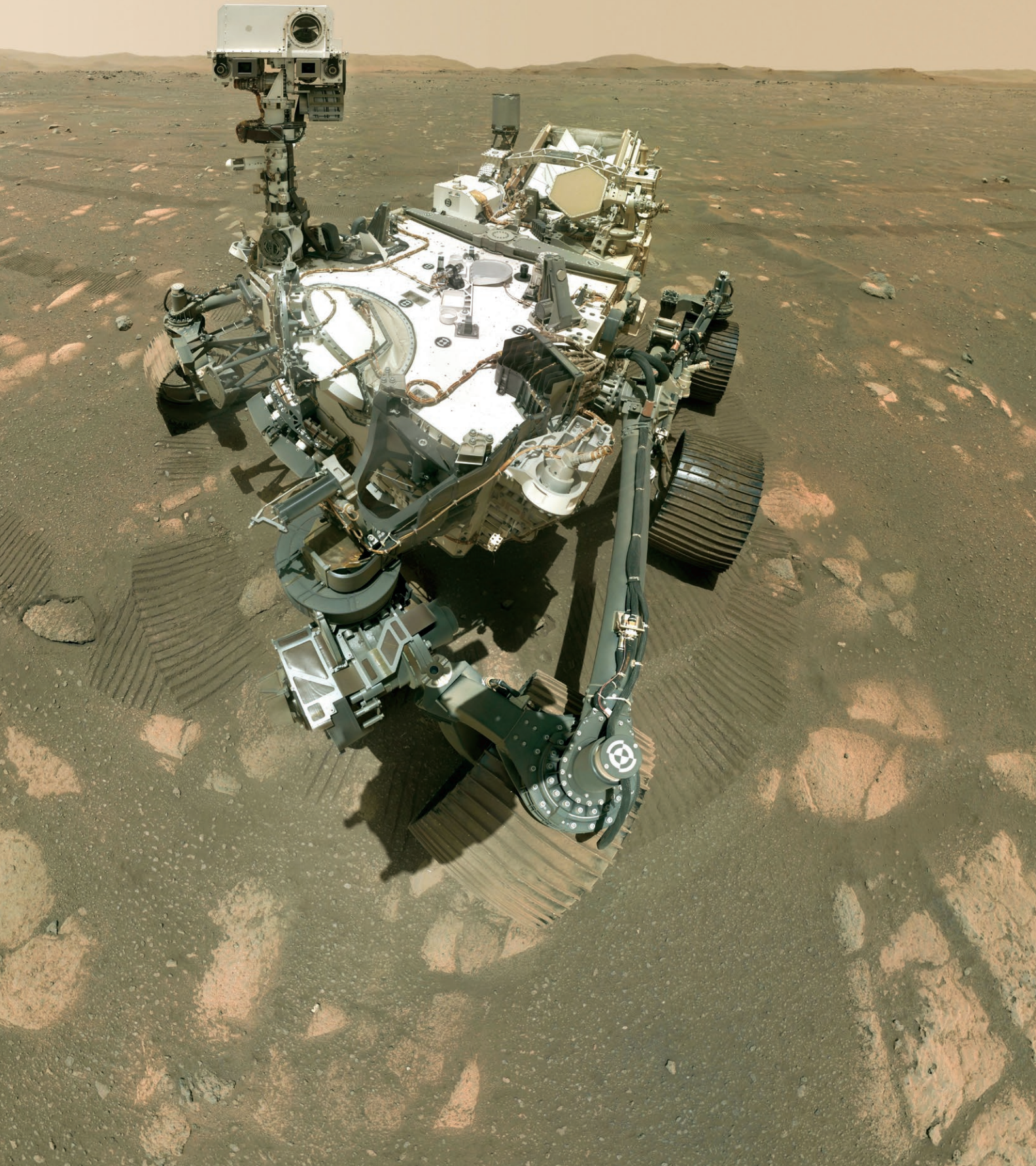
BELOW RIGHT Perseverance captured this image of its thruster-powered jetpack lowering the rover to the surface. Image processor Andy Saunders adjusted the image to show more accurate colors.

NASA/JPL-CALTECH/ANDY SAUNDERS



NASA's Perseverance Mars rover took this selfie with the Ingenuity helicopter in the background on the 46th Martian day, or sol, of the mission.

NASA/JPL-CALTECH/MSSS





Jupiter resembles a bowling ball in this picture that was created using four images captured by NASA's Juno spacecraft during a flyby in February 2021. Each white spot is a raging storm as large as Earth.

NASA/JPL-CALTECH/SwRI/MSSS/KEVIN M. GILL



NIGHT SKY PHOTOGRAPHY FOR BEGINNERS

by Navid Baraty

PHOTOGRAPHING THE ENDLESS wonders of the night sky is a highly rewarding experience that gives you a deeper connection to the universe. Though many modern smartphones have night-sky photography modes, a full-blown DSLR camera offers better clarity and the ability to bring out much greater detail than the human eye can see. Here are a few tips to help you get started.

BEFORE THE SHOOT

Timing and planning are as important for astrophotography as they are for everyday photography. Scout your shoot location ahead of time to get a sense of the layout and visualize your compositions. Consider including interesting features of the landscape in the foreground

of your image to help tell a story and convey a sense of place. Familiarize yourself with the night sky using apps and other resources. Know the moonrise time in your location as well as when the objects in which you're interested, such as the Milky Way, will rise and the direction they will travel overhead. PhotoPills is a fantastic photography app to use for planning.

Light pollution is an important consideration when selecting a shoot location. Get as far away from city lights as possible and if feasible, go to higher elevations where there are less particles in the air to scatter light. This will make your images clearer and more detailed. Shooting in colder temperatures will give you cleaner images due to your camera's sensor heating less during long exposures and generating less noise.

NIGHT SKY PHOTOGRAPHY FOR BEGINNERS

BASIC EQUIPMENT

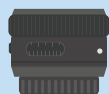
You don't need lots of expensive gear to capture beautiful images of the night sky. These four items are enough to get you started:



A camera with manual-mode functionality. Manually controlling the ISO, aperture and shutter speed is very important. For best results, use a full-frame camera, which will have a larger sensor to capture more light. Full-frame cameras also generate less noise at higher ISO settings.



A tripod sturdy enough for shooting long exposures in windy conditions. A ball-head mount on your tripod is much easier to use in the dark than a standard tripod mount.



If you're photographing the Milky Way, you'll want a wide-angle lens with a wide aperture (f/2.8 or lower if possible).



A shutter-release cable to help minimize any potential camera shake and enable you to shoot exposures longer than 30 seconds.

PHOTOGRAPHING THE MILKY WAY

There's nothing more incredible than seeing the grandeur of the Milky Way from a dark location. The Milky Way is best photographed during a new Moon or up to one week before or after, as the Moon's brightness will wash out your image.

When photographing the night sky, you need to account for Earth's rotation. You can only expose your image for a short time before the stars are no longer pinpoints and begin to trail in your image. Since you're trying to capture as much light from the sky as possible, it's important to use a wide-angle lens that has a large maximum aperture (f/2.8 or lower). A 14-24mm wide-angle zoom lens is ideal to use on a full-frame camera or a 10-20mm lens on a crop-sensor camera.



The Milky Way rises above the ponderosa pines of Sedona, Arizona on a chilly October night. As Baraty photographed the Milky Way aligning with this opening in the sky above, an approaching car at the campsite illuminated the trees midway through the 25-second exposure.

NAVID BARATY

To calculate how long your exposure can be before star trails appear, use the 500 rule:

FULL-FRAME CAMERAS:

$$\frac{\text{Maximum Exposure Time (in seconds)}}{1} = \frac{500}{\text{Focal Length}}$$

CROP-SENSOR CAMERAS:

$$\frac{\text{Maximum Exposure Time (in seconds)}}{1} = \frac{500}{(\text{Focal Length} \times 1.5)}$$

For example, if you're shooting at 14mm on a full-frame camera, the maximum exposure time would be 500/14, or around 35 seconds.



Star trails circle around the north celestial pole above the Temple of the Moon in Utah. This is a combination of 300 30-second exposures for a total exposure time of two and a half hours.

NAVID BARATY

Just remember that the 500 rule is a rule of thumb and should serve only as a starting point. You'll need to experiment and adjust your exposure times accordingly. As you become more familiar with photographing the night sky, you won't even need to reference it. Switch your wide-angle lens to manual focus and focus to infinity. You can then shoot at values in the following ranges to produce consistently great results:



Aperture
f/2–2.8



Exposure
10–30 seconds



ISO
1600–6400



Color balance
4000–5000K
(daylight/auto)

Try different settings in these ranges to find a combination that works best for your particular camera setup.



CAPTURING STAR TRAILS

We do everything possible to avoid star trails when shooting the Milky Way, but sometimes, the trails are exactly what we aim to capture. Long exposures of star trails create gorgeous images of the night sky that depict the passage of time.

In the Northern Hemisphere, all of the stars in the night sky appear to revolve around the North Star, or Polaris. If you shoot a long exposure with your camera pointed at Polaris, you'll notice that all of the stars circle around it. Use Polaris as your guide when choosing a direction to shoot. The two outermost stars in the bowl of the Big Dipper point to Polaris.

You have two options when shooting long exposures of star trails. You can either take a single long-exposure photograph using a very low ISO, or you can take a sequence of images that can be stacked in software, like StarStax. For example, instead of a single 60-minute exposure, you can shoot 120 images of 30-second exposures taken consecutively.

Stacking exposures is the recommended method. First of all, the longer your exposure, the more your camera sensor heats and generates noise in your image. Secondly, the stacking method makes it possible to photograph star trails in light-polluted areas. Even if you're in a bright city, you could shoot 1,000 images of two- or three-second exposures and still capture star trails. Finally, many different factors could ruin a single long exposure, such as a dead battery, a tripod shake or an unexpected light source entering the frame. While a wide-angle lens is best for the Milky Way, you can use a

lens of any focal length to photograph star trails. Note that the wider the lens, the longer you'll have to wait for star trails to fill your frame. If you remember the 500 rule example, you need to wait around 35 seconds for star trails to appear with a 14mm lens on a full-frame camera. Using an 85mm lens instead, you only need to wait 500/85, or about five seconds.

Using a longer focal length is your best choice if you want longer star trails to appear over a shorter period of time. Use the widest aperture setting on your lens so you can shoot at the lowest possible ISO when exposing your image. Always remember that a higher ISO means more noise.

Place your camera in continuous shooting mode and set the shutter speed to your desired exposure time. By locking down the shutter button on your shutter-release cable, your camera will take consecutive images as each exposure ends until you stop it. Alternatively, you can use the built-in intervalometer on your camera (if it has one) to set the desired parameters.

Don't forget to bring extra batteries! Long exposures and cold nights will quickly drain their life.

HAPPY SHOOTING

Photographing the night sky is a blank canvas of possibilities for a photographer. It will take a lot of experimentation to discover which settings work best for you. In the process, you'll gain a deeper understanding of the cosmos, and you'll increase your fascination with the night sky. 🌌

ABOVE These strange and otherworldly rock formations in Utah are known as the Candy Cliffs. This frame is a combination of 140 exposures. The stars trace three paths in the sky — those located along the celestial equator follow a straight line, while the others located on each side of the equator curve away.

NAVID BARATY



NAVID BARATY is a photographer and writer. He has a passion for capturing the night sky, cities from above, and dramatic landscapes. You can find more of Navid's photography work on Instagram @navidbaraty.



LET'S MOVE FORWARD TO 2022 TOGETHER

IMPORTANT TAX DEADLINES

For U.S. tax purposes, gifts must be received on or before the last day of the year. Here are some common methods of making a gift and their associated deadlines.

Online credit card gifts: transaction completed by 11:59 p.m. EST (8:59 p.m. PST), December 31, 2021

Checks sent via U.S. mail: postmarked on or before December 31, 2021

Checks sent via third-party shipping (such as FedEx or UPS): delivered on or before December 31, 2021

Credit card gifts via U.S. mail: received and processed on or before December 31, 2021

Stock transfer: broker-to-broker instructions issued in time for completed transfer on or before December 31, 2021

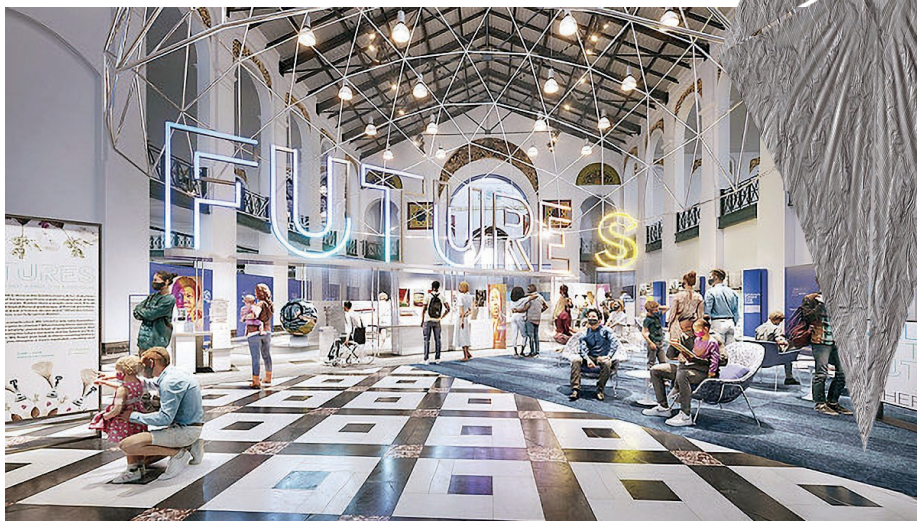
For more ways to give, visit planetary.org/giving

Thanks to members like you, The Planetary Society has made great strides in 2021. We truly rely on your contributions to **explore worlds** by increasing discoveries about our solar system and beyond ... **find life** beyond Earth by elevating our search ... and **defend Earth** by decreasing our risk of being hit by an asteroid.

Space science and exploration — and the benefits they provide to humankind — are vital to our shared dream of a positive future! That's why your year-end support is so important.

Please visit planetary.org/planetaryfund to make the most generous donation you can. Everyone here at The Planetary Society is grateful for your loyal support — **thank you!**





LIGHTSAIL 2 GOES ABOVE AND BEYOND

ABOVE The Smithsonian's Arts + Industries building is now home to FUTURES, the first building-wide exploration of the future on the National Mall in Washington, D.C.

THE SMITHSONIAN INSTITUTION/
ROCKWELL GROUP

Our crowdfunded solar sailing spacecraft has been in orbit for more than two years now, and it's doing more than what was ever thought possible. LightSail 2 continues to expand our understanding of solar sailing, with new science and engineering goals set for its extended mission. It's also informing new solar sailing missions, starting with NASA's upcoming NEA Scout. As if that wasn't enough, LightSail 2 continues to inspire the public to dream bigger about what's possible when people work together. The Smithsonian's FUTURES exhibition, which opened this November, showcases the science of solar sailing and tells the story of how tens of thousands of people (you!) came together to make this groundbreaking mission happen. We're all looking forward to seeing what LightSail 2 will accomplish next thanks to your ongoing support as a member — this year, you donated more than \$150,000 to support the extended mission!



CELEBRATING SPACE AROUND THE WORLD

October 2021 was a big month for celebrating space, and we were proud to collaborate internationally to make the most of it. For International Observe the Moon Night on October 16, we connected our members and audiences around the world with events happening in their area and online to celebrate our celestial companion and the inspiring work being done to understand it. For World Space Week (October 4-10), we helped promote this year's official theme, Celebrating Women in Space, by partnering with the World Space Week Association, the SETI Institute and Unistellar to inspire a passion for space in girls around the world.



CONNECTING WITH LEADERS IN SPACE

This year, The Planetary Society was invited to meet privately with the leaders of two national space agencies to deepen the impact we have on space science and exploration. NASA administrator Bill Nelson met with our CEO, Bill Nye, and our Chief of Washington Operations, Brendan Curry, to explore new ways for the Society to support NASA's work. Canadian Space Agency President Lisa Campbell met with our Canadian Space Policy Adviser, Kate Howells, and other Society leadership to extend her appreciation for our advocacy work in Canada and to set the stage for more collaboration to come. We are honored to connect directly with these leaders, and we are excited to create new opportunities for you to make an impact on the future of space.

BELOW The 19 nonprofit charitable organizations that received a \$1 million grant from Blue Origin's foundation, Club for the Future, to inspire future generations to pursue careers in STEM and help invent the future of life in space.

BLUE ORIGIN



THE PLANETARY SOCIETY RECEIVES A MAJOR GRANT

The great work that your membership supports was recognized this year by Blue Origin's nonprofit foundation, Club for the Future, which selected The Planetary Society as one of 19 organizations to receive a \$1 million grant. These funds don't come with any requirements other than to support our energetic strategic plan, Space for Everyone, as we continue to increase public involvement in advancing planetary exploration, searching for life beyond Earth and defending Earth from dangerous asteroids and comets. As a Planetary Society member, you can be proud of the recognition we continue to receive as one of the world's leading space organizations. We're looking forward to all we can accomplish together with the support of this grant.



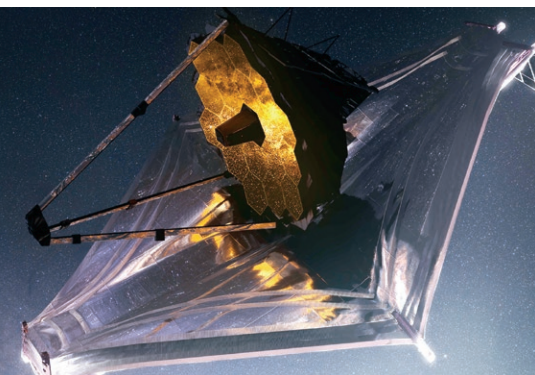
PLANETARY ACADEMY IS ABOUT TO LAUNCH!

We are beyond thrilled to announce our first-ever youth membership program: Planetary Academy. This new program, designed for curious kids between the ages of 5 and 9, aims to spark a lifelong passion for space exploration. Every quarter, Planetary Academy members will receive a package from us that includes hands-on activities, experiments, word games, creative projects, images and facts about our solar system and special gifts. Academy members will build their knowledge about the intriguing worlds of our solar system and the spacecraft exploring them. Planetary Academy will go live in spring 2022. Be on the lookout in your email inbox for the official announcement!



THE 2022 DAY OF ACTION IS COMING UP

Each year, The Planetary Society's Day of Action brings people from around the world together to advocate for space. In the United States, we arrange meetings for members to speak directly with their representatives in Congress about how important space science and exploration are to them and to advocate for specific priorities in the exploration of other worlds, the search for life and planetary defense. We also create opportunities for people in other countries to take action by advocating for these priorities to their own representatives. No matter where you live, we encourage you to take part in the 2022 Day of Action on March 8. We'll provide training, talking points and tips on effective advocacy that will help you make your voice heard. If you're in the United States, you can register to join other U.S.-based advocates in virtual meetings with Congress. Elsewhere, you can sign up to join advocates around the world in a unified call for investment in space. Go to planetary.org/dayofaction to learn more.



JOIN US FOR THE JWST LAUNCH

Although launch dates tend to slip, at the time of publication, NASA is expecting to send the James Webb Space Telescope into orbit on December 18, 2021. This is right around the time The Planetary Report usually reaches members' mailboxes, but we wanted to mention the launch just in case you're reading this before it happens. The launch of JWST is not something you want to miss! The mission has been in development since 1996, and just about every space enthusiast on the planet has been waiting for this launch with bated breath. You can find the official NASA feed of the launch alongside our best resources about the mission at planetary.org.

GIVE THE GIFT OF SPACE

If you celebrate a gift-giving holiday or are just always on the lookout for fun space stuff, you'll want to check out our annual space gift guide. This year, we asked our members to recommend the coolest cosmic clothing, jewelry, toys, books and more to create the ultimate guide to space gifts in 2021. Go to planetary.org/giftguide2021 to learn more.

A membership
to The Planetary
Society always
makes a perfect gift!
planetary.org/gift





Voyager 2 acquired the images for this high-resolution mosaic of Triton on Aug. 25, 1989. The south pole is at the left; several of Triton's famous south polar geysers are visible. Toward the equator at right, Triton is covered with a strange "cantaloupe terrain."

NASA/JPL/TED STRYK

EARLY MORNING PLANET SPLENDOR

IN THE SKY

Planets move from the evening sky to the morning sky during this period. In December and into January, in a line low in the west from the horizon up are super-bright Venus, yellowish Saturn and bright Jupiter. Mercury dances past Venus toward Saturn during this period. Reddish Mars is low in the pre-dawn east in December. By mid-January, it is joined by Venus and then briefly in February by Mercury, then Saturn and finally Jupiter in March. The Quadrantids meteor shower peaks the night of January 2-3. The Quadrantids is an above-average shower, and the Moon is new, so moonlight won't interfere this year. For more night sky tips, you can always check out planetary.org/night-sky.

RANDOM SPACE FACT

Triton has over 99% of the total mass of Neptune's moon system. Triton is thought to be a captured object, and the capture process may have resulted in the elimination of many of Neptune's original moons.

TRIVIA CONTEST

Our June solstice contest winner is Chris Mills of Arlington, Virginia, USA. Congratulations! The question was: **What is the largest asteroid considered to be a near-Earth object (NEO)?** The answer: **1036 Ganymed with a diameter of about 35 kilometers (22 miles).**

Try to win a copy of "Astronomy for Kids" by Bruce Betts and a Planetary Radio T-shirt by answering this question: **Of the 88 modern constellations agreed upon by the International Astronomical Union (IAU), which is the smallest in area (solid angle subtended)?**

Email your answer to planetaryreport@planetary.org or mail your answer to The Planetary Report, 60 S. Los Robles Ave., Pasadena, CA 91101. Make sure you include the answer and your name, mailing address and email address (if you have one). By entering this contest, you are authorizing The Planetary Report to publish your name and hometown. Submissions must be received by March 1, 2022. One entry per person. The winner will be chosen in a random drawing from among all the correct entries received. For a weekly dose of What's Up? complete with humor, a weekly trivia contest and a range of significant space and science fiction guests, listen to Planetary Radio at planetary.org/radio.



Please contact Terri or Taunya at Betchart Expeditions for brochures and updated information on COVID and travel. Call 1-800-252-4910 or go to betchartexpeditions.com.

There are wonderful travel adventures ahead for you in 2022 with The Planetary Society. You can sail the Caribbean, watch the aurora borealis dance across the Alaskan sky or see a lunar eclipse!

ALASKA AURORA BOREALIS MARCH 10-16, 2022

Reserve your place now on this ever-popular winter-in-Alaska program, with dazzling evenings watching the aurora borealis.

TALL SHIP CARIBBEAN SAILING ADVENTURE MARCH 19-26, 2022

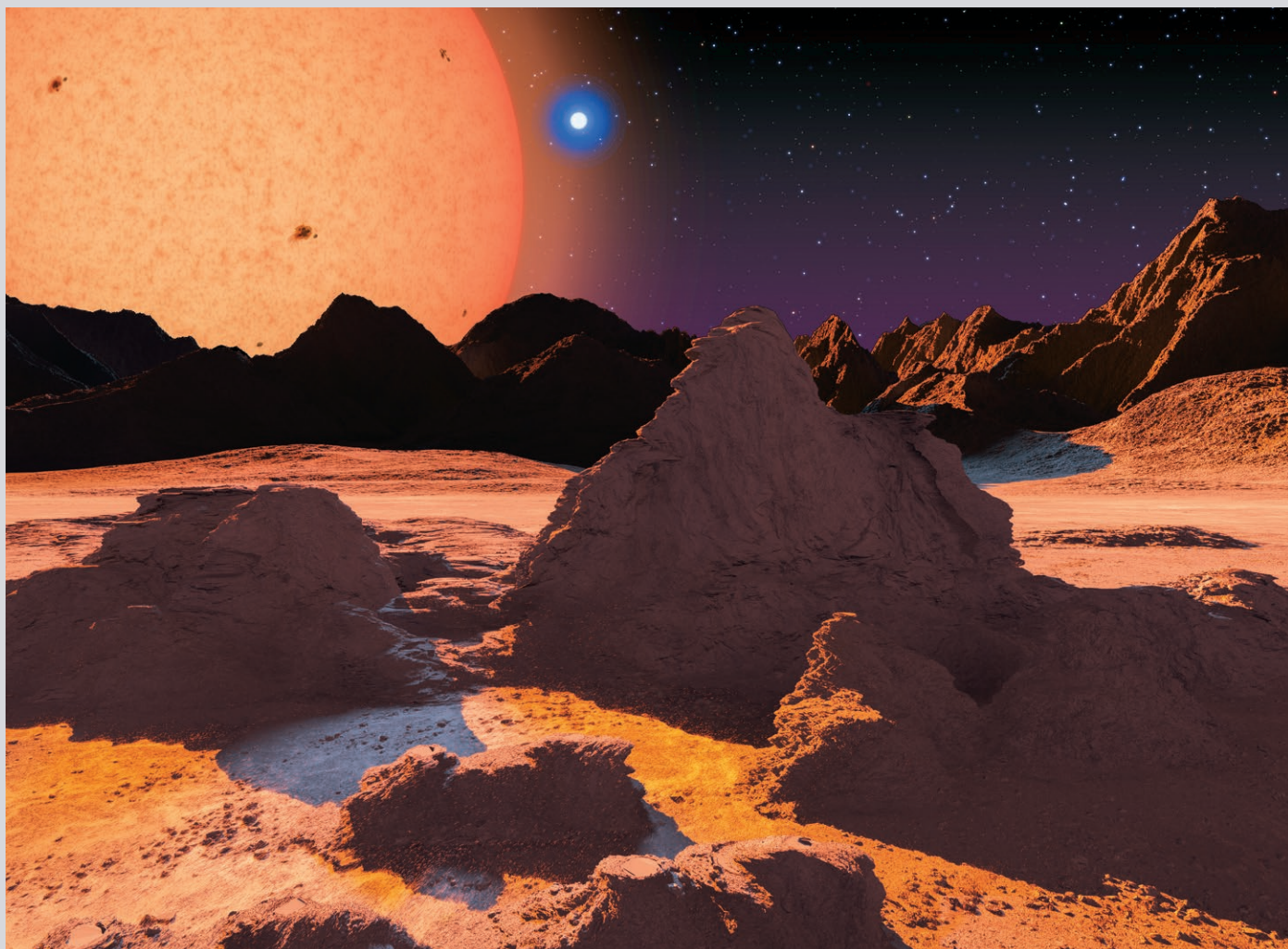
Travel on board the four-masted Star Flyer and explore the fascinating islands in the Leeward Isles. Join this fascinating trip with Dr. Tyler Nordgren.

GALAPAGOS ISLANDS TOTAL LUNAR ECLIPSE MAY 11-20, 2022

There is nothing like a lunar eclipse over the Galapagos Islands. The whole sky will sparkle with starlight in this super dark-sky location!

HAWAII TOTAL LUNAR ECLIPSE NOVEMBER 6-14, 2022

See a total lunar eclipse and explore the natural wonders of Hawaii. We will also show you some of the astronomical observatories that generate an enormous amount of information about our solar system, galaxies, black holes and beyond!



Robin Pleak, "Binary System"

There are some astronomical views that can't yet be captured by spacecraft instruments. A vista like this one — the surface of a planet orbiting a red giant star with a smaller blue companion — can only be captured by the imagination of an artist. Planetary Society member and space artist Robin Pleak created this spectacular image of a view we know must exist somewhere in the cosmos but that we have yet to see for ourselves. By creating artwork like this, Pleak helps remind us that there is so much more out there to explore.

Do you want to see your artwork here? We love to feature our members throughout this magazine. Send your original, space-related artwork to connect@planetary.org.